

Applicant : Anatoli Verentchikov et al.
Appln. No. : 10/561,775
Page : 2

Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims

1. (previously presented) A multi-reflecting time-of-flight mass spectrometer (MR-TOF MS) comprising:

an ion source;

an ion receiver downstream from said ion source;

at least one ion mirror assembly intermediate said ion source and said ion receiver and elongated in a shift direction for improving sensitivity and resolution of the MR-TOF MS;

a drift space intermediate said ion mirror assembly; and

a lens assembly disposed within said drift space along said at least one shift direction and with a period in said shift direction corresponding to ion shift per integer number of ion reflections,

said ion source, ion receiver, ion mirror assembly and said drift space arranged to provide a folded ion path between said ion source and said ion receiver composed of at least one reflection by said ion mirror assembly for separating ions in time according to their mass-to-charge ratio (m/z) so that a flight time of the ions is substantially independent of ion energy.

2. (canceled)

3. (previously presented) The MR-TOF MS as defined in claim 1, further comprising: a timed ion selector including one of a Bradbury-Nielsen ion gate, a parallel plate deflector, and a control grid within said ion receiver.

Applicant : Anatoli Verentchikov et al.
Appln. No. : 10/561,775
Page : 3

4. (previously presented) The MR-TOF MS as defined in claim 1, wherein said ion source comprises one of an ion storage device and an ion accelerator.
5. (previously presented) The MR-TOF MS as defined in claim 1, wherein said ion source comprises a continuous ion source.
6. (previously presented) The MR-TOF MS as defined in claim 1, wherein said ion source comprises one of a SIMS, a MALDI, and an IR-MALDI.
7. (previously presented) The MR-TOF MS as defined in claim 5, wherein said ion source comprises one of an ESI, an APCI, an APPI, an EI, a CI, a PI, an ICP, a gas-filled MALDI, an atmospheric MALDI, a gaseous ion reaction cell, a DC/field asymmetric ion mobility spectrometer, and a fragmentation cell.
8. (previously presented) The MR-TOF MS as defined in claim 1, wherein said ion receiver includes an ion detector having an extended dynamic range.
9. (previously presented) The MR-TOF MS as defined in claim 1, wherein said ion receiver comprises a gas-filled cell selected from one of a fragmentation cell, a molecular reaction cell, an ion reaction cell, electron capture dissociation, ion capture dissociation, a soft deposition cell, and a cell for surface ion dissociation.
10. (previously presented) A multi-reflecting time-of-flight mass spectrometer (MR-TOF MS) comprising:
 - an ion source;
 - an ion receiver downstream from said ion source;
 - at least one ion mirror assembly intermediate said ion source and said ion receiver and elongated in a shift direction for improving sensitivity and resolution of the MR-TOF MS; and
 - a drift space intermediate said ion mirror assembly,

Applicant : Anatoli Verentchikov et al.
Appln. No. : 10/561,775
Page : 4

said ion source, ion receiver, ion mirror assembly and said drift space arranged to provide a folded ion path between said ion source and said ion receiver composed of at least one reflection by said ion mirror assembly for separating ions in time according to their mass-to-charge ratio (m/z) so that a flight time of the ions is substantially independent of ion energy,

wherein said ion mirror assembly comprises a plurality of electrodes shaped and spaced relative to one another to provide a spatial ion focusing and time-of-flight focusing of ions substantially independent of ion energy and on ion position in a plane transverse to said ion path.

11. (previously presented) The MR-TOF MS as defined in claim 1, wherein said ion mirror assembly includes one of a parallel assembly of conductive square frames, slotted plates, bars, and rods, each having an optional edge termination.

12. (previously presented) The MR-TOF MS as defined in claim 1, wherein at least a portion of said ion mirror assembly is operably connected to a pulsed voltage supply for gating ions in or out of the MR-TOF MS.

13. (previously presented) The MR-TOF MS as defined in claim 1, wherein said ion mirror assembly comprises at least two electrodes having voltages of opposite polarities relative to the other to form an attractive lens.

14. (previously presented) The MR-TOF MS as defined in claim 1, wherein said drift space comprises an ion deflector connected to one of a DC voltage supply and a pulsed voltage supply.

15. (previously presented) The MR-TOF MS as defined in claim 2, wherein said lens assembly includes at least two lenses elongated transversely to said ion path.

Applicant : Anatoli Verentchikov et al.
Appln. No. : 10/561,775
Page : 5

16. (previously presented) The MR-TOF MS as defined in claim 4, wherein said ion storage device comprises a gas-filled set of electrodes having a radio-frequency (RF) voltage applied to at least one of said electrodes.

17. (previously presented) The MR-TOF MS as defined in claim 4, wherein said ion storage device comprises a plurality of sets of electrodes having a radio frequency (RF) voltage applied to at least one electrode in a first set of electrodes and a pulse voltage applied to at least one electrode in a second set of electrodes.

18. (previously presented) The MR-TOF MS as defined in claim 4, wherein said ion accelerator comprises a pulsed orthogonal accelerator.

19. (previously presented) The MR-TOF MS as defined in claim 4, wherein said ion accelerator comprises a plurality of electrodes, each having a slit along said shift direction of the MR-TOF MS.

20. (previously presented) The MR-TOF MS as defined in claim 4, wherein said ion accelerator comprises one of a pulsed ion mirror assembly and a pulsed portion of said ion mirror assembly.

21. (previously presented) The MR-TOF MS as defined in claim 4, wherein said ion accelerator comprises one of an accelerator with pulsed voltages and an accelerator with static voltages.

22. (previously presented) The MR-TOF MS as defined in claim 5, wherein said continuous ion source comprises an intermediate ion storage guide preceding said ion storage device and having a gas pressure greater than said ion storage device.

Applicant : Anatoli Verentchikov et al.
Appln. No. : 10/561,775
Page : 6

23. (previously presented) The MR-TOF MS as defined in claim 5, wherein said continuous ion source comprises at least two gas-filled sets of electrodes having a radio-frequency (RF) voltage applied to at least one set of said gas-filled electrodes.

24. (previously presented) The MR-TOF MS as defined in claim 8, wherein said ion detector comprises one of a secondary electron multiplier having at least one dynode, a scintillator and photomultiplier, a micro-channel, micro-sphere plates, at least two channels of detection, and at least two anodes each connected to a data acquisition system having an analog-to-digital converter (ADC).

25. (previously presented) The MR-TOF MS as defined in claim 8, wherein said ion detector dynamic range is extended by alternating scans with various intensities of said pulsed ion source.

26. (previously presented) The MR-TOF MS as defined in claim 8, wherein said ion detector dynamic range is extended by alternating scans with varying durations of ion injection into an ion storage device.

27. (currently amended) The MR-TOF MS as defined in claim 9, wherein said gas-filled cell includes at least one electrode connected to a radio-frequency (RF) voltage for one of dampening ion kinetic energy in gas collisions, stabilizing internal ion energy, confining ions, fragmenting ions, selecting ion species and retaining ions for exposure to reactant particles.

28. (previously presented) The MR-TOF MS as defined in claim 14, wherein said ion deflector comprises at least one steering plate.

29. (previously presented) The MR-TOF MS as defined in claim 14, wherein said ion deflector is located on a far side of said shift axis opposite to said ion source for steering ions in a static mode to change direction of said ion path.

Applicant : Anatoli Verentchikov et al.
Appln. No. : 10/561,775
Page : 7

30. (previously presented) The MR-TOF MS as defined in claim 14, wherein said ion deflector is located on a similar side of said shift axis as said ion source for directing ions toward one of an off-axis detector and an MR-TOF MS analyzer, and revert in a direction of ion shift for a time of ion confinement within the MR-TOF MS.

31. (previously presented) The MR-TOF MS as defined in claim 16, wherein said gas-filled set of electrodes comprises at least one of an ion guide having a plurality of elongated rods, a 3-D quadrupole ion trap, a linear ion trap with ion ejection, an RF channel with at least one electrode having an opening for ion passage, a ring electrode trap, a hybrid ion guide with a 3-D ion trap, and a segmented analog of the aforementioned electrodes formed of at least two plates.

32. (previously presented) The MR-TOF MS as defined in claim 5, wherein said ion storage device includes one of a filter of ion components, a discriminator of ion components, and a suppressor of ion components.

33. (previously presented) A tandem time-of-flight mass spectrometer apparatus, comprising:
a pulsed ion source;
said MR-TOF MS of claim 1 provided to separate parent ions;
a fragmentation cell downstream of said MR-TOF MS for fragmenting the parent ions into daughter ions; and
a mass spectrometer downstream of said fragmentation cell for detecting said daughter ions;
wherein said at least one ion mirror assembly comprises two grid-less and parallel ion mirrors separated by a drift space and substantially elongated in one shift-direction.

34. (original) The mass spectrometer apparatus as defined in claim 33, further comprising an ion selector subsequent said fragmentation cell.

Applicant : Anatoli Verentchikov et al.
Appln. No. : 10/561,775
Page : 8

35. (previously presented) The mass spectrometer apparatus as defined in claim 33, wherein said fragmentation cell comprises a gas-filled cell having a differential pumping stage and an ion focusing device.

36. (original) The mass spectrometer apparatus as defined in claim 33, wherein said fragmentation cell comprises an internal gas pressure P associated with a cell length L ($P \cdot L$) above 0.2 Torr*cm.

37. (original) The mass spectrometer apparatus as defined in claim 33, wherein said fragmentation cell comprises a gas pressure $P > 0.5$ Torr and $L < 1$ cm.

38. (original) The mass spectrometer apparatus as defined in claim 33, wherein said fragmentation cell comprises a gas filled set of electrodes having a radio frequency (RF) voltage applied to at least one of said electrodes for confining ions in radial direction.

39. (previously presented) The mass spectrometer apparatus as defined in claim 33, wherein said fragmentation cell further comprises a set of electrodes connected to one of a DC and slow-varying voltage to form an axial DC electric field, and an axial moving-wave electric field to control velocity of ion motion in said fragmentation cell, said DC voltage being applied to one of the same set of electrodes and a dissimilar set of electrodes.

40. (original) The mass spectrometer apparatus as defined in claim 33, wherein said mass spectrometer downstream of said fragmentation cell comprises a time-of-flight mass spectrometer (TOF MS).

41. (original) The mass spectrometer apparatus as defined in claim 40, wherein said TOF MS comprises an orthogonal ion accelerator.

Applicant : Anatoli Verentchikov et al.
Appln. No. : 10/561,775
Page : 9

42. (original) The mass spectrometer apparatus as defined in claim 40, wherein said TOF MS comprises ion path less than, and an acceleration voltage greater than in said MR-TOF MS to produce an ion flight time in said TOF MS at least 100-fold less than in said MR-TOF MS.

43. (original) The mass spectrometer apparatus as defined in claim 40, wherein said TOF MS comprises a data system adapted for parallel acquisition of daughter spectra without mixing spectra corresponding to different parent ions.

44. (original) The mass spectrometer apparatus as defined in claim 40, wherein said TOF MS includes a first and a second multi-reflecting time-of-flight mass spectrometer (MR-TOF MS).

45. (original) The mass spectrometer apparatus as defined in claim 44, wherein said second MR-TOF MS is substantially identical in construction to said first MR-TOF MS.

46. (original) The mass spectrometer apparatus as defined in claim 41, wherein said orthogonal ion accelerator is grid-less.

47. (previously presented) The mass spectrometer apparatus as defined in claim 45, wherein the second MR-TOF MS forming said TOF MS comprises a plurality of deflectors cooperating with lenses in said drift space to adjust a flight path of the ions in said TOF MS.

48. (previously presented) A tandem multi-reflecting time-of-flight mass spectrometer (MR-TOF MS-MS) apparatus comprising:

 a first multi-reflecting time-of-flight mass spectrometer (MR-TOF MS) for separating parent ions;

 a fragmentation cell attached to said first MR-TOF MS for receiving said parent ions;
and

 a second MR-TOF MS attached to said fragmentation cell for mass analysis of daughter ions exiting said fragmentation cell, wherein at least one of said MR-TOF MS comprises at

Applicant : Anatoli Verentchikov et al.
Appln. No. : 10/561,775
Page : 10

least two grid-less and parallel ion mirrors separated by drift space and substantially elongated in one shift-direction,

wherein at least one of said first and second MR-TOF MS comprises:

an ion source;

an ion receiver downstream from said ion source;

at least one ion mirror assembly intermediate said ion source and said ion receiver and elongated in a shift direction for improving sensitivity and resolution of the MR-TOF MS;

a drift space intermediate said ion mirror assembly; and

a lens assembly disposed within said drift space along said at least one shift direction and with a period in said shift direction corresponding to ion shift per integer number of ion reflections,

said ion source, ion receiver, ion mirror assembly and said drift space arranged to provide a folded ion path between said ion source and said ion receiver composed of at least one reflection by said ion mirror assembly for separating ions in time according to their mass-to-charge ratio (m/z) so that a flight time of the ions is substantially independent of ion energy.

49. (canceled)

50. (original) The tandem MR-TOF MS-MS apparatus as defined in claim 48, further comprising a timed ion selector between said first MR-TOF MS and said fragmentation cell.

51. (original) The tandem MR-TOF MS-MS apparatus as defined in claim 48, wherein said fragmentation cell further comprises at least one set of electrodes connected to one of DC and slow varying voltage to form one of a respective axial DC electric field or an axial moving-wave electric field, controlling velocity of ion motion within said fragmentation cell, and said DC voltage being applied to at least one electrode in said at least one set as RF voltage.

Applicant : Anatoli Verentchikov et al.
Appln. No. : 10/561,775
Page : 11

52. (original) The tandem MR-TOF MS-MS apparatus as defined in claim 48, wherein said fragmentation cell further includes a gas at a gas pressure (P) above $P \cdot L > 0.2 \text{ Torr} \cdot \text{cm}$.

53. (original) The tandem MR-TOF MS-MS apparatus as defined in claim 48, wherein said fragmentation cell comprises a differential pumping stage and an ion focusing assembly.

54. (original) The tandem MR-TOF MS-MS apparatus as defined in claim 48, wherein said fragmentation cell comprises at least one gas-filled set of electrodes having a radio frequency (RF) voltage applied to at least one electrode within said set of electrodes to confine ions in a radial direction.

55. (currently amended) The tandem MR-TOF MS-MS apparatus as defined in claim 48, wherein said fragmentation cell comprises means for ion storage and pulsed ejection[5] in one of an axial and an orthogonal direction.

56. (original) The tandem MR-TOF MS-MS apparatus as defined in claim 52, wherein said second TOF MS comprises an orthogonal ion accelerator.

57. (original) The tandem MR-TOF MS-MS apparatus as defined in claim 55, wherein said second MR-TOF MS comprises means for adjusting an ion path less than, and an acceleration voltage greater than, said first MR-TOF MS such that a flight time in said TOF MS is at least 100-fold less compared to said flight time in said first MR-TOF MS.

58. (original) The tandem MR-TOF MS-MS apparatus as defined in claim 54, wherein said second MR-TOF MS comprises a data system providing parallel acquisition of daughter spectra without mixing spectra from unrelated parent ions.

59. (original) The tandem MR-TOF MS-MS apparatus as defined in claim 58, wherein said second MR-TOF MS comprises a lens assembly disposed within said drift space.

Applicant : Anatoli Verentchikov et al.
Appln. No. : 10/561,775
Page : 12

60. (original) The tandem MR-TOF MS-MS apparatus as defined in claim 59, wherein said lens assembly comprises at least one deflector configured to adjust a flight path of ions in said second MR-TOF MS.

61. (currently amended) A multi-reflecting time-of-flight mass spectrometer (MR-TOF MS-MS) apparatus comprising:

- a multi-reflecting time-of-flight mass spectrometer (MR-TOF MS); and

- a fragmentation cell connected to said MR-TOF MS and configured to revert ions within said MR-TOF MS to employ the same MR-TOF analyzer for analysis of both parent ions and fragment ions, wherein said MR-TOF MS comprises an assembly of two grid-less and parallel ion mirrors separated by drift space and substantially elongated in one shift-direction,

- wherein said MR-TOF MS comprises:

- an ion source;

- an ion receiver downstream from said ion source;

- at least one ion mirror assembly intermediate said ion source and said ion receiver and elongated in a shift direction for improving sensitivity and resolution of the MR-TOF MS;

- a drift space intermediate said ion mirror assembly; and

- a lens assembly disposed within said drift space along said at least one shift direction and with a period in said shift direction corresponding to ion shift per integer number of ion reflections,

- said ion source, ion receiver, ion mirror assembly and said drift space arranged to provide a folded ion-path between said ion source and said ion receiver composed of at least one reflection by said ion mirror assembly for separating ions in time according to their mass-to-charge ratio (m/z) so that a flight time of the ions is substantially independent of ion energy.

62-79. (canceled)